RPR NETWORK SYSTEM

BACKGROUND OF THE INVENTION

The invention relates to a ring network, and

5   particularly to a system and an implementation technology for actualizing MAC (media access control) bridging on RPR (Resilient Packet Ring) protocol mainly defined by IEEE802.17.

The RPR is a network protocol technology mainly

10   aiming at being provided a network for connecting between cities, such as MAN/WAN (Metropolitan Area Network/Wide Area Network). An examination of the RPR is underway in order to establish a draft at the IEEE802.17 Committee. As of September in 2002, Draft

15   version 1.0 (tentative specifications) as first standard specifications were released, at which stage they were approved at the meeting at the end of September, and the final specifications are scheduled to be determined in March in 2003 through necessary

20   modifications thereafter. The RPR is based on SRP (Spatial Reuse Protocol) released by Cisco Corp. and has the following features.

1. The RPR supports a bidirectional dual ring network.

2. The RPR supports a MAC layer in layer 2.

25   3. An effective utility rate of a using bandwidth is high.

4. The RPR supports Plug & Play.

5. A protection switching time is sub-50 ms.

Note that the SRP is described in, for instance, a Patent document 1.

The following points in addition to the above-mentioned are characteristic of the RPR.

1. There are three priority classes, and it is easy to implement QoS (Quality of Service) control on the high-order layer.

2. A protection switching system is a steering protection (which is a system for switching a route having a failure to another route of a reversed direction along the ring, and a wrapping protection (which is a system for turning the route having a failure back in the reversed direction along the ring just anterior to a failure point) is an option.

3. The RPR is a system that is limited to the MAC layer in the regulations and does not depend on the lowest-order layer (the physical layer).

The RPR is a novel MAC layer protocol and terminates the MAC frame. Accordingly, a basic idea has hitherto been such that a device (a RPR device) implementing the protocol should be a device (which is router, gateway, and the like) executing a layer process higher than this. At the recent IEEE meetings, however, an examination for defining a forwarding method so that the RPR device can function as a device (which is a so-called bridge) capable of

transparently forwarding the MAC frame, is underway.

With respect to the forwarding method, a good deal of problems and methods for solutions thereof are presented, and finally a forwarding method based

5   on IEEE802.1D was proposed. The proposed method also, however, has a problem, and, in the present, standards of the forwarding method are not yet taken shape.

For describing the technology according to the

10 invention of the present application, the following terms will at first be defined.

(1) MAC frame: the "MAC frame" is a frame having a MAC header. Herein, this indicates a frame of the Ethernet (registered trademark) defined in

15 IEEE802.3 and a frame having a RPR MAC header defined in IEEE802.17. Especially in the case of distinguishing therebetween, there are called an "EMAC frame" and a "RMAC frame", respectively. FIG. 17 shows formats of the EMAC frame and the RMAC frame.

20 (2) Node: the "node" is a device for actualizing the RPR protocol. Each node exists on bidirectional dual rings (two counter-rotating ringlets). In the specification, the node might be called a "RPR node" and also called a "RPR device".

25 (3) Station: the "station" is a device that terminates the MAC frame. The station receives the MAC frame and transfers a data field thereof to a

high-order layer. Further, the station assembles the
MAC frame including data from the high-order layer
and transmits it. When the station receives the MAC
frame, if the MAC frame has an error, or a
5   destination MAC address (MAC DA) of the MAC frame is
not coincident with a MAC address of the station
itself, the MAC frame is basically discarded. In
case a receipt frame is a RMAC frame, however, the
RMAC frame is made to pass through on the side
10   opposite to the side of having received it. In a
case where a node (a RPR node) that performs
processing of the RPR protocol has functions as the
station, the node is called a "station node".

   (4) Bridge: the "bridge" is a device that
15   forwards the MAC frame as far as any error does not
occur. Normally, the bridge copies and distributes
the MAC frame received at one of physical ports to
all other physical ports. Further, the bridge has a
MAC address learning function, and creates and keeps
20   a table (called "a port-to-MAC address mapping table"
or "MAC learn table") from MAC DA/SA (source address)
of MAC frames to be forwarded, The table shows a
physical port to which a device indicated by the
source/destination addresses of the MAC frame is
25   connected.   The bridge checks MAC DA/SA of each
received MAC frame. If the MAC SA is not registered
in the table, the bridge registers the MAC SA with an

identifier of a physical port (e.g., port number) received the MAC frame to the table. Further, if the MAC DA is already registered in the table, the bridge forwards the MAC frame to only a physical port corresponding to the MAC DA by referring the table. An extra load is thereby prevented from being applied to other ports. In a case where the node (the RPR node) performing the processing of the RPR protocol has the bridge function, this node is called a "bridge node".

Next, a method of transmitting and receiving the RMAC frame between the stations, which is tentatively defined in IEEE802.17, will be at first explained as a prior art (see, for instance, Non-Patent document 1).

FIG. 18 shows one example of a RPR network. FIG. 18 shows a plurality of nodes SA-SL as station nodes each having the station function. The nodes SA-SL are sequentially connected in a ring-shape in a state (sequence) illustrated in FIG. 18 via bidirectional communication lines (two counter-rotating ringlets). Normally, an optical fiber is used as communication line. Herein, for the sake of explanation, the RPR network is defined as follows.

<1> MAC addresses of the respective nodes are:

SA: MSA, SB: MSB, … SL: MSL

<2> Clockwise connecting sequence (outer ringlet) is:

SA → SB → SC … SL → SA

<3> Counterclockwise connecting sequence (inner) is:

SA → SL→ SK … SB → SA

In the RPR, it is defined that a node, when receives a MAC frame, performs processes as below.

(A) An error check is conducted based on FCS/HEC of the MAC frame, and, if there is an error, the MAC frame is discarded.

(B) In case there is no errors, the MAC DA of the MAC frame is checked, if the MAC DA is coincident with a MAC address of the node itself, the MAC frame is captured inside, and a data field thereof is transferred onto the high-order layer.

(C) When the MAC address is not the MAC address of the node itself, the MAC SA is checked. If the MAC SA is coincident with the node's MAC address, the MAC frame is discarded.

(D) In case it is not coincident, a value of TTL (Time to Live) of the MAC frame is checked. If the TTL value is under 1 (not TTL = 1), the MAC frame is discarded.

(E) When the TTL value is 1 or more (TTL = 1 is established), one (1) is subtracted from the present TTL value, and the MAC frame is reassembled (concretely, the HEC and FCS are recalculated) and transmitted to a next neighboring node (which is called "pass").

Accordingly, the node SA shown in FIG. 18, in the case of transmitting a frame to the node SD, assembles a RMAC frame as shown in FIG. 19.

Normally, each node (the node SA) transmits the
5 frame onto a ringlet of a direction (which is called "near (short) direction") that the number of nodes forwarding the frame is small. Therefore, the node SA transmits the frame to the outer ringlet.

The frame reaches at first the node SB. The node SB,
10 as the MAC DA of the frame is not coincident with the MAC address of the node SB itself, lets the frame pass through (to be concrete, transmits the frame to the neighboring node SC corresponding to the next node). At this time, one is subtracted from the TTL
15 value of the frame. The node SC executes the same process as the node SB does, and the frame arrives at the node SD. The node SD, as the MAC DA of the frame is coincident with the MAC address of the node SD, captures the frame inside the node SD, and transfers
20 the data field of the frame onto the high-order layer, thus completing the process.

For executing the process described above, each node is required to specifically grasp the number of forwarding nodes, each of which exists between a
25 source node (node itself) and the destination node, with respect to each direction of ringlet (outer and inner ringlets). In the RPR protocol, for achieving

the object, a control packet that is called a topology discovery packet for grasping a topology of the ring (each ringlet), is transferred and received between the RPR nodes. The topology discovery packet

5   includes the MAC addresses, as pieces of information, of the source node itself and the neighboring nodes thereof. Each of the nodes receiving the topology discovery packet adds a piece of self-information (a MAC address of the node itself) and sends it to the

10 neighboring node. These processes are executed each node. Eventually all the nodes are thereby able to know the MAC addresses of all other nodes and the number of the forwarding nodes (which is precisely a value of TTL needed for the frame transmission).

15 Each node retains them as a topology map table. By way of an example, FIG. 20 (Table 1) shows the topology map table retained on the node SA illustrated in FIG. 18. Note that the topology discovery packet is, when in an initial setting in

20 addition to when adding and deleting the nodes, periodically transmitted and received between the respective nodes, whereby updated information of the network can be kept at all times.

Further, in case of failures occurred in the

25 node or on the communication line between the nodes, each node, when detects the failures, sends a control packet called a protection packet to all other nodes.

Each of the nodes is thereby notified of a change of the topology. The change of the topology is immediately reflected in the topology map table. By way of an example, FIG. 21 (Table 2) shows a change

5   of the topology map table when a failure occurred on the communication line for transmitting the frame the node SD from the node SC to the node SD illustrated in FIG. 18. Thus, a state of the topology is reflected in the topology map table. Thereby, it is

10   indicated that the node SA cannot perform communications, about each node further than the node SD, by using the outer route. Therefore, the node SA can actually judge that using the inner route to perform communications to each node further than the

15   node SD. Such a technology is called steering and is one of the principal technologies of the RPR.

Now, in the case of applying the RPR to a normal network, other than the nodes on the rings, a variety of networks such as the Ethernet, etc. are

20   normally connected, and it is required that the communications between stations (off-the-ring stations), each of which is located in the outside of the rings and is accommodated to one of nodes (on-the-ring nodes) on the rings, be possible.

25   Originally, the RPR is based on an assumption that the frame is routed between the off-the-ring stations via the high-order layer. Namely, the MAC

frame, which has been received by the node on the ring and comes from the off-the-ring station, is temporarily designated in its forwarding destination (other on-the-ring node) by the high-order layer and is then transmitted as a frame of a RPR MAC layer onto the ring. Then, the frame is received by a different node on the ring, then also designated in its forwarding destination (an off-the-ring station) by the high-order layer, and transmitted to a destination station after becoming a frame of an outside protocol. This forwarding procedure indicates that the node on the ring must invariably be a router. In the case of the same layer protocol as the RPR where the frame dealt with by the off-the-ring station is an Ethernet frame, etc., however, there is a large load in terms of a cost and a speed.

The IEEE802.17 Committee, for solving the above problem, assumes a MAC bridging system for giving a bridge function of forwarding the MAC frame with no intermediary of the high-order layer, and is going to incorporate a function of making the RPR node function as a bridge into the rules. At the present, a prospective rule on the occasion of actualizing the function may be a transparent bridge system, defined in IEEE802.1D, and the rules of IEEE802.17 will be settled in the direction (refer to, e.g., Non-Patent documents, 2, 3, 4, 5).

The transparent bridge system has, however, some problems that will be given as follows. The IEEE802.17 Committee also pointed out the problem, and, in the present situation, tangible standard rules of the bridge function are not yet seen.

A bridge device for executing MAC bridging, in the case of being installed as, for instance, a bridge node on the RPR network defined in IEEE802.17 as shown in FIG. 22, must be capable of the following communications (refer to, e.g., Non-Patent document 6).

1) SX-BJ-BD-SY communications (bidirectional)

2) SX-BJ-SA communications (bidirectional)

3) SA-SG communications (bidirectional, bridge pass)

For enabling all these communications, a transparent bridge system of IEEE802.1D was proposed at the IEEE802.17 Committee. In the case of applying the system directly to the node in the RPR network, the bridge node executes frame processing (a transparent translation) shown in FIG. 23.

In FIG. 23, the on-the-ring bridge node executing the framing processing learns information about which on-the-ring bridge a MAC address off the ring where the communications are performed is linked to, and sorts out it into a table. The communications 1) through 3) can be thereby performed. The transparent bridge system has, however, the

following problems pointed out by the IEEE802.17
Committee (refer to, e.g., Non-Patent document 7).

A relationship between the MAC address of the
bridge node and the MAC address of the off-the-ring
5   device connected to the bridge node, remains
unlearned. Therefore, in the bridge node through
which the frame addressed to the off-the-ring device
is passed, the frame is copied addressed to the
network connected to the bridge nodes (which is
10 called blooding), and there is a possibility of
increasing the load on the network.

According to the RPR, normally in the case of
transmitting the MAC frame from a certain node on the
ring to a different unspecified node, in a ringlet
15 selection, the smaller in TTL is to be selected. In
a case where BJ-BD distances are equal in the network
illustrated in FIG. 22, normally any one of the
routes is predetermined. Herein, in the case of
transmitting the frame on a route of SX → BJ → SA →
20 BD → SY, the bridge nodes BL, BC existing in the
middle of the route can learn from the passing frame
that the station SX is connected to the bridge node
BJ.

The bridge node, however, in the case of not
25 yet learning that the station SY is connected to the
bridge node BD, there being a possibility that
station SY might be connected to the self-device (the

bridge node itself), therefore copies the frame simultaneously when it passes through and transmits the frame to the off-the-ring network connected to the self-device. Moreover, the bridge nodes BF, BI

5   through which the frame does not pass are unable to learn that the station SX is connected to the bridge node BJ.

Supposing that there is a response on the higher-layer than the station SY, the frame is

10 transmitted to the station SX and transferred across a route of SY → BD → SG → BJ → SX (because if the respective stations take the same algorithm, the equal distance implies a selection of the same direction), in which case the bridge nodes BF, BI can

15 learn that the station SY is connected to the bridge node BD. The bridge nodes BL, BC are, however, unable to learn. Further, the bridge nodes BF, BI do not yet learn that the station SX is connected to the bridge node BJ, and therefore send a copy of the

20 frame to the network off the ring.

When the frame arrives finally at the station SX from the station SY, the communications between the stations SX-SY via the outer route (the above route) become possible. However, the intermediate

25 bridge nodes BL, BC, BF and BI cannot ever learn the address of the frame passing through the nodes themselves, resulting in a constant occurrence of the

blooding (see FIG. 24: for example, Non-Patent document 8, slides 11 and 12).

As a method of preventing the problem given above, there is a method of sending a response
5 thereof in the frame-coming direction. For instance, the bridge node BJ starts transmitting round the outer ring to the station SY, and the bridge node BD also starts transmitting round the outer ring to the station SX. In the method, in a case where the
10 respective stations SX, SY simultaneously transmit the frames to the destinations, the frames are passed round the outer ring and reach the destinations, while responses thereof are returned round via the inner ring to the destinations, and further responses
15 thereof go round the outer ring and so on, resulting in an oscillating state where the destinations are floating. This induces a possibility in which the frame sequence might be reversed depending on a delay of frame transmission (refer to, e.g., Non-Patent
20 document 8, slides 7 and 8).

Further, as shown in FIG. 22, the communications between the stations SZ-SY involve using in principle a shorter route. Accordingly, the bidirectional communications via a route of SZ-BL-SA-
25 BD-SY, are performed. Herein, if the communication line to BL → SA is disconnected (cut off), the communications round the outer ring in a direction of

SZ → SY cannot be carried out. Hence, the inner ring
is used according to the steering. At this time, the
respective bridge nodes BJ, BF, BI did not learn that
the station SY is connected to the bridge BD.

5   Accordingly, the flooding occurs. Besides, a
response thereof is sent via a route of SY → BD → SA
→ BL → SZ round the inner ring as it used to be so
far. This makes it impossible forever to learn f
about the address mapping described just above (see

10   FIG. 25: for instance, Non-Patent document 9, slides
11 and 12).

As a method of preventing the aforementioned
problem, there is a method of transmitting the
response in the frame-coming direction in the same

15   way as in the first problem. If a longer route
between the bridge nodes BD-BL is selected, however,
there are a larger number of cross-over nodes than by
selecting the shorter. Accordingly, more of the
whole usable bands are used up as a result. In other

20   words, the load on the network rises.

Thus, the transparent bridge system in the
present situation has a possibility that an extra
load increases in some cases.

<2> For the reason of a reliability, etc., the

25   frame addressed to the device on the off-the-ring
network connected to the plurality of bridge nodes
has no information about where to go and might be

lost.

As shown in FIG. 29, it is considered from a point of view of the reliability that the off-the-ting station SY is connected to the two bridge nodes BC, BD on the ring. At this time, the selection of the connection between the station SY and the bridge nodes BC, BD, is determined by applying Spanning Tree Protocol defined in IEEE802.1D. Supposing that a route between BC-SY is selected, for instance, the frame is transmitted and received between the SX-SY via the bridge node BC, and each of the on-the-ring nodes learns that the station SY is connected to the bridge node BC (FIG. 26: normal state).

Herein, if a failure occurs between BC-SY, the station SY selects a route between BD-SY in accordance with the Spanning Tree Protocol. The bridge node BC, however, simply judges that the communications with the station SY fall into a failure, and there is no method of knowing that the bridge node BD can surrogate. Hence, the frame sent addressed to the station SY is taken back by the bridge node BC, wherein the frame is judged to have the failure and discarded. Accordingly, all the frames from the station SX to the station SY do not reach in spite of an existence of the route of BD-SY (FIG. 27: failure state between BC-SY). This makes it meaningless to connect the station SY to both of the

bridges BC and BD in order to enhance the reliability (refer to, e.g., Non-Patent document 8, slides 9 and 10).

As a plan for solving the problem, the
5   IEEE802.17 Committee proposed that a flooding bit is provided in the RPR header. The processing is executed so that all the nodes on the ring can receive the frame in which the flooding bit is set irrespective of whatever destination it may have.
10 FIG. 28 shows diagram of this concept. The plan enables the frame to reach the destination even in such a case as <2> by creating a method of flooding the frame to all the node at all times. Further, all of the node can always learn the same content.
15 Accordingly, any problem as in <1> does not arise.

The use of the communication bands of almost all the nodes for a certain frame, however, conduces to a loss of Spatial Reuse (a reuse of a space) that is greatly characteristic of the RPR. As a matter of
20 fact, the system based on the plan described above comes to have substantially the same operation as the frame is transmitted and received in a case where the bridge device on the Ethernet actualized at the present is connected onto the ring. Therefore, a
25 problem occurs afresh, wherein the meaning of utilizing the RPR is lost.

These problems are derived from the RPR MAC

header destination address becoming none of the
addresses of the nodes on the ring because of
transmitting the frame transparently. In other words,
the on-the-ring node that should receive (should do

5   forwarding) cannot be designated uniquely by the MAC
address, which becomes a factor for causing the
respective problems as described above by the
transparent bridge system.

Such being the case, the IEEE802.17 Committee

10   is examining a method of scheming to obviate the
problems in such a form as to add an original EMAC
address to the RMAC frame in the case of translating
the EMAC frame into the RMAC frame. This is called
an enhance bridge system. The following format plans

15   are proposed for the system.

(Plan-A) A system for transmitting and
receiving by adding the MAC address to the RPR format

FIG. 29 shows a format plan in which the MAC
address is added. This plan-A is a method of

20   invariably adding an address, as a destination, of
the on-the-ring node to the Ethernet frame coming
from outside the ring by the on-the-ring node. The
plan-A is capable of obviating the problems. In
order to make the off-the-ring MAC address

25   corresponding to the on-the-ring MAC address, a
transparent bridge learns which bridge node on the
ring the station off the ring is connected to and

sorts out it into a table format (e.g., Non-Patent document 9, slide 17).

The plan-A has, however, the following defects. Namely, the plan-A has not compatibility with the RPR format used so far. Therefore, a device manufactured base don the plan-A is impossible of communicating with the existing device. This implies that an existing LSI for the RPR MAC layer processing that has been designed for the RPR device, cannot be used. Further, in the plan-A, al the nodes on the ring must execute the process (the process of adding the on-the-ring MAC address). Hence, in the communications between the station nodes on the ring, the same address must be set in the RPR MAC address and in the MAC address. This kind of process is futile as far as the communications between the on-the-ring station nodes are concerned. Moreover, the format related to the plan-A has such an aspect that the overhead is always large and data communication efficiency is poor.

(Plan-B) A plan for distinguishing by a flag as to whether the MAC address is added or not

An addition of the MAC address is originally a piece of information needed only for the case where the bridge is related to the communications. Accordingly, there is considered a plan for adding the MAC address only in such a case that one (or

both) of the transmitting and receiving sides is the bridge node. This plan-B is shown in FIG. 30. A difference between the plan-A and the plan-B is given as follows. Namely, the plan-A is that the format is changed by adding the RPR MAC address at all times. By contrast, the plan-B is that the RPR MAC address is added only in a required case, and the communications are performed in the existing format other than this case. Accordingly, the addition of the RPR MAC address is not applied to the communications between the station nodes on the ring.

The on-the-ring bridge node and station node, however, must distinguish between the addition and non-addition of the MAC address, depending on the communication partner. Therefore, the information (flag: 1 bit at the minimum) for judging whether the MAC address is added to the RPR header or not, is needed.

The plan-B has the following defects. Namely, the format to which the flag is added as in the plan-B has no compatibility with the original format as in the plan-A. Further, the plan-B must involve adding the flag to the RPR header afresh. Hence, there is no compatibility with the device manufactured based on the existing specifications, and the existing RPR MAC layer LSI can not be used. The plan-B, however, unlike the plan-A, enables the communications with

the existing device with respect to the communications between the station nodes. Moreover, in the plan-B, the RPR MAC address is not always added. Therefore, the overhead for a whole traffic

5   is smaller than the plan-A.

(Plan-C) A plan for encapsulating the whole frame in the bridge

For giving the compatibility to the format, there is considered a method of encapsulating the

10 whole MAC frame (EMAC frame) with the RPR MAC frame in the bridge. A format related to the plan-C is shown in FIG. 31 (for example, Non-Patent document 9, slide 21, Non-Patent document 10, and slide 11).

The plan-C has a necessity of registering

15 afresh ET (Ethernet Type) for indicating encapsulation (an application to IETF is required). It is not a problem to simply encapsulate the MAC frame in the plan-C. If this remains as it is, it follows that protocols (IEEE802.1Q-VLAN, MPLS, etc.)

20 for adding a label to between the header and the payload can not be supported (IEEE802.17 has a rule enabling these protocols to be supported. For processing on these protocols, new ETs are also required to be registered, and the ETs just

25 corresponding to the number of protocols for processing are needed.

In any plan among the plans A through C

explained above, in the case where the transmitting destination is the off-the-ring station subordinate to the bridge, when a mapping between the MAC address of the station and the MAC address of the on-the-ring

5   bridge node is learned, the transmission becomes possible by adding the MAC address corresponding to a transmitting source and a destination on the ring.

In the case of newly adding the station subordinate to the bridge, there is a case where a

10   mapping relationship therebetween is not yet learned. In this case, it is required that the frame be sent to all the nodes (precisely to only the bridges therein). Hence, a broadcast MAC address is added as a destination MAC address. The frame (the RPR frame)

15   to which the broadcast MAC address is added, is received by each of the nodes. The bridge node receiving the RPR frame translates the RPR frame into an Ethernet frame and thus sends it to all the subordinate ports off the ring. If there is a device

20   8a device having MACDA of the Ethernet frame) having the MAC address in any one of the off-the-ring ports, the device is capable of receiving a desired Ethernet frame. The station ruled out of the destination of the Ethernet frame receives the Ethernet frame,

25   interprets its body frame and thereafter discards it.

For actualizing the processes described above, in any plan among the plans A through C, the new

format (or the encapsulated format) to which the MAC address is added must be interpreted by the node (see FIG. 32). This implies that neither the plan-A nor the plan-B nor the plan C enables the device for

5   processing only the existing format to be disposed within the ring (see FIG. 33).

For others, technologies described in the following Non-Patent documents 11 through 17 are given as the prior arts related to the invention of

10 this application.

[Patent document 1] Specification of U.S.P.6314110

[Non-Patent document 1] IEEE Draft P802.17/D1.0 (P802-17D1-ob.pdf), chapters 5, 6, 8 and 10, Internet, <URL:http://www.ntp.net.fujitsu.co.jp/StOrg/IEEE/>

15 [Non-Patent document 2] Bridging Ad-Hoc (BAH) Overview (bah-upd-01.pdf), Internet, <URL:http://www.ieee802.prg/17/documents/presentation s/may2002/index.htm>

[Non-Patent document 3] Bridging on 802.17 LAN with

20 802.1D/Q Compliance (bah-dot1-01.pdf), Internet, <URL:http://www.ieee802.org/17/documents/presentation s/may2002/index.htm>

[Non-Patent document 4] Basic Bridging Compliance (bah-basic-03.pdf), Internet,

25 <URL:http://www.ieee802.org/17/documents/presentation s/jul2002/index.htm>

[Non-Patent document 5] Enhanced Bridging Spatial

Reuse of 802.17 Bridge Traffic (bah-enhnc-02.pdf),
Internet,
<URL:http://www.ieee802.org/17/documents/presentation
s/jul2002/index.htm>

[Non-Patent document 6] IEEE802.17 Frame Structure
and Bridging Ad-Hoc Support (bah-frm-01.pdf), Slides
11, 17, 21, Internet,
<URL:http://www.ieee802.org/17/documents/presentation
s/may2002/index.htm>

[Non-Patent document 7] Flooding in 802.17 Networks
(bah-fld-01.pdf), Internet,
<URL::http://www.ieee802.org/17/documents/presentatio
ns/may2002/index.htm>

[Non-Patent document 8] 802.1D/Q Compliance and
Spatial Reuse (bah-spt-01.pdf), Slides 7-8, 9-10, 11-
12, Internet,
<URL:http://www.ieee802.org/17/documents/presentation
s/may2002/index/htm>

[Non-Patent document 9] BAH 802.17 Frame Structure
Requirements (bah-frame-02.pdf), Slide 11, Internet,
<URL:http://www.ieee802.org/17/documents/prsentations
/ju;2002/index.htm>

[Non-Patent document 10] BAH Summary (bah-motion),
Internet,
<URL:http://www.ieee802.org/17/documents/presentation
s/may2002/index.htm>

[Non-Patent document 11] 802.17 presentations (bah-

fld-01.pdf), Internet,

<URL:http://www.ieee802.org/17/documents/presentation
s/jul2002/index.htm>

[Non-Patent document 12] Bridging Ad-Hoc (BAH)
Overview (bah-over-01.pdf), Internet,

<URL:http//www.ieee802.org/17/documents/presentations
/jul2002/index.htm>

[Non-Patent document 13] 802.17 Bridging Compliance
Roadmap (bah-road-01.pdf), Internet,

<URL:http//www.ieee802.org/17/documents/presentations
/jul2002/index.htm>

[Non-Patent document 14] TA Document IEEE802.17-11
Jul2001/0.40:3, October 2001 (Basic-Bridging-Draft-
Text.pdf), Internet,

<URL:http://www.ieee802.org/17/documents/presentation
s/jul2002/index.htm>

[Non-Patent document 15] Proposed D0.3 Changes for
Enhanced Bridging July 1, 2002 RESILIENT PACKET RING
(RPR) (bridge-spat-draft02.pdf), Internet,

<URL:http://www.ieee802.org/17/documents/presentation
s/jul2002/index.htm>

[Non-Patent document 16] IEEE Draft P802.17/D0.3
Contribution, DRAFT STANDARD FOR (Flooding.pdf),
Internet,

<URL:http://www.ieee802.org/17/documents/presentation
s/jul2002/index.htm>

[Non-Patent document 17] IEEE Draft P802.17/D0.3

Contribution June 28, 2002, RESILIENT PACKET RING
(RPR) (Formats.pdf), Internet,
<URL:http://www.ieee802.org/17/documents/presentation
s/jul2002/index.htm>

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SUMMARY OF THE INVENTION

One of the objects of the invention is to
provide, with respect to the problems described above,
a technology related to a RPR network that eliminates
10   a necessity for a distinguishing flag/ET indicating
that a MAC address is added and a frame is
encapsulated.

Further, one of the objects of the invention is
to provide a technology related to the RPR network in
15   which a bridge node on a ring has means for receiving
a frame with an unknown address.

The invention adopts the following
architectures in order to solve the problems
described above.

20   Namely, the invention is a RPR network system
in a RPR network where a plurality of station nodes
terminating a MAC frame and a plurality of bridge
nodes forwarding the MAC frame are connected to one
or more rings,

25   wherein each of the station nodes, in the case
of transmitting the MAC frame to other station node,
transmits a RPR MAC frame in which a MAC address of

the other station node is set in a destination MAC

address, and transmits, in the case of transmitting

the MAC frame to a station off the ring that is

connected an unspecified bridge node, a RPR MAC frame

5   into which this MAC frame is encapsulated in such a

state that the unspecified bridge node can capture it,

each of the bridge node, in the case of

receiving the MAC frame in which a MAC address of the

off-the-ring station connected to other bridge node

10   is set in a destination address from the off-the-ring

station connected to the bridge node itself,

transmits a RPR MAC frame into which the MAC frame is

encapsulated in such a state that he other bridge

node can capture it, and, in the case of receiving a

15   MAC frame in which a MAC address of an unspecified

station node is set in a destination MAC address from

the off-the-ring station connected to the bridge node

itself, transmits the MAC frame in a way that

translates it into a RPR MAC frame,

20   each of the station nodes captures the RPR MAC

frame that is not encapsulated, and

each of the bridge nodes captures the RPR MAC

frame into which the MAC frame is encapsulated, and

transmits the MAC frame within the captured RPR MAC

25   frame to the off-the-ring station connected to the

bridge node itself.

In the invention, the MAC frame is, for example,

an EMAC frame, and the RPR frame is a RMAC frame.

Further, the invention can be applied to a ring network configured of one or more rings, for instance, a RPR network configured of bidirectional dual rings examined by IEEE802.17, wherein station nodes and bridge nodes exist in mixture.

The station node has a function of executing a process of terminating a MAC frame, i.e., a function of becoming a transmitting source and a transmitting destination. Further, the bridge node has a function of forwarding the MAC frame to a network on the same or a different protocol as or from the protocol possessed by the bridge node itself without terminating the MAC frame.

Moreover, the station node, when transmitting the MAC frame to the station on the same ring, can be constructed to assemble a RPR MAC frame in a RPR MAC format defined in IEEE802.17 and to thus transmit it.

Furthermore, the station node, when transmitting the MASC frame to the off-the-ring station connected to an edge of the bridges on the same ring, can be constructed to translate the MAC frame into a format suited to an off-the-ring protocol, then set it as a data field, further translate it into a format of its being encapsulated in the RPR MAC format, and transmit it to the bridge node on the ring.

Further, when the station off the ring
transmits the MAC frame to the station node on the
same ring via the bridge node on the ring, it can be
constructed to transparently translate the MAC frame
5   sent from the off-the-ring station into the RPR MAC
frame in the bridge node on the ring and to transmit
it to the on-the-ring station node.

Moreover, when transmitting the MAC frame to
the off-the-ring station connected to an edge of
10   other bridge nodes on the same ring, it can be
constructed to set the MAC frame sent from the off-
the-ring station it as a data field in the on-the-
ring bridge node, then translate it into a format of
its being encapsulated in the RPR MAC format, and
15   transmit it to other bridge node on the ring.

This enables an architecture wherein the on-
the-ring station node receives the MAC frame
invariably in the RPR MAC frame format, the on-the-
ring bridge receives invariably the RPR MAC frame
20   into which the MAC frame based on the connection
protocol with the off-the-ring station is
encapsulated, and the bridge decapsulates it and
performs forwarding of it to the station as an off-
the-ring recipient.

25   According to the invention, there is no
necessity from the receiving side to judge whether
the frame received by the on-the-ring station node

and bridge node is encapsulated or not. Namely, the station node and the bridge node, which correspond to the receiving sides of the RPR MAC frame, may not judge whether the MAC frame is encapsulated or not.

5   Accordingly, the distinguishing flag and special ET explained in the prior art are not needed. A compatibility with the existing RPR nodes can be thereby maintained.

It is preferable that the invention be

10   constructed such that each of the station nodes and each of the bridge nodes have a table registered with the MAC addresses of all the station nodes and bridge nodes connected to the rings,

each of the station nodes, in the case of

15   transmitting the MAC frame, transmits the MAC frame in a RPR MAC format if the destination MAC address of the MAC frame is registered in the table, and transmits the RPR MAC frame into which the MAC frame is encapsulated if the destination MAC address is not

20   registered in the table, and

each of the bridge nodes, in the case of forwarding the MAC frame received from the off-the-ring station connected to the bridge node itself, transmits the MAC frame in a way that translates the

25   MAC frame into the RPR MAC frame if the destination MAC address of the MAC frame is registered in the table, and transmits the RPR MAC frame into which the

MAC frame is encapsulated if the destination MAC address is not registered in the table.

As the table, there can be applied, for instance, a topology map table specified to be included according to RPR, registered with the MAC addresses of all the stations/bridges on the rings, distances/directions from the self-station/bridge.

This being thus done, when the on-the-ring station node transmits the MAC frame and when the on-the-ring bridge node routes the MAC frame, if the destination MAC address thereof is registered in the table, the recipient is judged to be the on-the-ring station, whereas if not registered, the recipient is judged to be the off-the-ring station, and it is possible to determine whether the transmission object MAC frame is transmitted transparently as it is or the MAC frame is encapsulated.

Moreover, it is preferable that the invention be constructed such that each of the station nodes and each of the bridge nodes have a mapping table stored with the MAC addresses of the bridge nodes and the MAC addresses of the off-the-ring stations connected to the bridge nodes in a way that make them corresponding to each other, and

each of the station nodes and each of the bridge nodes, in the case of transmitting the RPR MAC frame into which the MAC frame is encapsulated, set

the MAC address of the bridge node in a destination
MAC address of the RPR MAC frame when the mapping
table is stored with the bridge node MAC address
corresponding to the destination MAC address of the
5   MAC frame.

Still further, it is preferable that the
invention be constructed such that each of the
station nodes and/or each of the bridge nodes retain
a multicast address to a group which all the
10 plurality of bridge nodes belong to, and

each of the station nodes and each of the
bridge nodes, in the case of transmitting the RPR MAC
frame into which the MAC frame is encapsulated, set
the multicast address in a destination MAC address of
15 the RPR MAC frame when the mapping table is not
stored with the bridge node MAC address corresponding
to the destination MAC address of the MAC frame.

Thus, the multicast MAC address to a group into
which all the bridges on the ring are set, is
20 registered, and the frame is transmitted to reach all
the bridge nodes by setting the destination MAC
address of the RPR MAC frame (into which the MAC
frame is encapsulated) to the multicast address when
unable to uniquely designate the destination MAC
25 address of the RPR MAC frame. The encapsulated MAC
frame can be thereby made to reach the off-the-ring
station as an edge to the bridge nodes.

Namely, it is feasible to provide means for allowing only the on-the-ring bridge node to receive the frame with its address unknown.

Moreover, it is preferable that the invention

5   be constructed such that each of the bridge nodes, in the case of transmitting the RPR MAC frame into which the MAC frame is encapsulated and in which the bridge node MAC address corresponding to the destination MAC address of the MAC frame is set in a destination MAC

10 address, sets its own MAC address in a source MAC address of the RPR MAC frame, and

the station node and/or the bridge node forwarding the RPR MAC frame into which the MAC address transmitted from the bridge node is

15 encapsulated, stores the mapping table with a source MAC address of the RPR MAC frame and a source MAC address of the MAC frame within the RPR MAC frame in a way that makes them corresponding to each other.

Further, the invention is a bridge node

20 connected, together with a plurality of station nodes terminating a MAC frame, to one or more rings configuring a RPR network,

wherein the bridge node, in the case of receiving the MAC frame in which a MAC address of

25 other off-the-ring station connected to other bridge node connected to the ring is set in a destination MAC address, transmits a RPR MAC frame into which the

MAC frame is encapsulated in such a state that the other bridge node can capture it, and

the bridge node, in the case of receiving the MAC frame in which a MAC address of an unspecified station node is set in a destination MAC address from the station, transmits the MAC frame in a way that translates the MAC frame into a RPR MAC frame.

Still further, the invention is a station node connected, together with a plurality of bridge nodes forwarding a MAC frame, to one or more rings configuring a RPR network,

wherein the station node, in the case of transmitting the MAC frame transmitted to other station not connected to the ring, transmits a RPR MAC frame in which a MAC address of the other station node is set in a destination MAC address, and

the station node, in the case of transmitting the MAC frame to the off-the-ring station connected to an unspecified bridge node, transmits the RPR MAC frame into which the MAC frame is encapsulated in such a state that the unspecified bridge node can capture it.

Moreover, the invention is a RPR card installed into a bridge node connected, together with a plurality of station nodes terminating a MAC frame, to one or more rings configuring a RPR network,

wherein the RPR card, in the case of receiving

the MAC frame transmitted from a station off the ring
and in which a MAC address of other off-the-ring
station connected to other bridge node is set in a
destination MAC address, transmits a RPR MAC frame
5   into which the MAC frame is encapsulated in such a
state that the other bridge node can capture it, and
        the RPR card, in the case of receiving the MAC
frame in which a MAC address of an unspecified
station node is set in a destination MAC address from
10 the station, transmits the MAC frame in a way that
translates the MAC frame into a RPR MAC frame.
        Further, the invention is a MAC frame
forwarding method for a bridge node connected,
together with a plurality of station nodes
15 terminating a MAC frame, to one or more rings
configuring a RPR network,
        wherein the bridge node transmits, in the case
of receiving the MAC frame transmitted from an off-
the-ring station and in which a MAC address of the
20 other off-the-ring station connected to other bridge
node connected to the ring is set in a destination
MAC address, a RPR MAC frame into which the MAC frame
is encapsulated in such a state that the other bridge
node can capture it, and
25   the bridge node transmits, in the case of
receiving the MAC frame from the station in which a
MAC address of an unspecified station node is set in

a destination MAC address, the MAC frame in a way that translates the MAC frame into a RPR MAC frame.

Furthermore, the invention is a MAC frame forwarding method for a RPR card installed into a
5   bridge node connected, together with a plurality of station nodes terminating a MAC frame, to one or more rings configuring a RPR network,

wherein the RPR card transmits, in the case of receiving the MAC frame transmitted from an off-the-
10   ring station and in which a MAC address of the other off-the-ring station connected to other bridge node connected to the ring is set in a destination MAC address, a RPR MAC frame into which the MAC frame is encapsulated in such a state that the other bridge
15   node can capture it, and

the RPR card transmits, in the case of receiving the MAC frame from the station in which a MAC address of an unspecified station node is set in a destination MAC address, the MAC frame in a way
20   that translates the MAC frame into a RPR MAC frame.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a diagram showing a format translation method according to the invention;
25   FIG. 2 is an explanatory diagram of a frame transmission in a case where a mapping relationship of a MAC address is not yet learned;

FIG. 3 is a diagram showing an IP network model by way of an embodiment of the invention;

FIG. 4 is an IP/MAC address table on each device (a RPR node) in the embodiment;

5 FIG. 5 is a diagram showing an example of a topology map table retained on each RPR node shown in FIG. 3;

FIG. 6 is an explanatory diagram of an ARP frame format between stations in the embodiment;

10 FIG. 7 is an explanatory diagram of a format of an IP data packet (an IP frame) transferred and received between the stations in the embodiment;

FIG. 8 is an explanatory diagram of a format of an ARP frame forwarded between a station node and the 15 station;

FIG. 9 is an explanatory diagram of a format of the IP data packet forwarded between the station node and the station;

FIG. 10 is a diagram showing an example of a 20 structure of a bridge node;

FIG. 11 is a block diagram showing an example of a structure of a RPR card shown in FIG. 10;

FIG. 12 is a diagram showing an example of a data structure of a learning table/MAC address 25 mapping table;

FIG. 13 is a flowchart showing a RPR MAC frame transmitting process by the station node;

FIG. 14 is a flowchart showing a RPR MAC frame transmitting process by the bridge node;

FIG. 15 is a flowchart showing a RPR MAC frame receiving process by the bridge node;

5   FIG. 16 is a flowchart showing a RPR MAC frame receiving process by the station node;

FIG. 17 is an explanatory diagram of formats of the EMAC frame and the RMAC frame;

FIG. 18 is a diagram showing an example of a

10   RPR network;

FIG. 19 is an explanatory diagram of assembling the RMAC frame;

FIG. 20 is a table (Table 1) showing an example of a table (a topology map table) retained by the

15   node on the ring;

FIG. 21 is a table (Table 2) showing an example the topology map table of the node after a failure has occurred between the nodes on the ring;

FIG. 22 is a diagram showing an example of the

20   RPR network in which the station nodes and the bridge nodes exist in mixture;

FIG. 23 is an explanatory diagram of a frame process executed by a transparent bridge pursuant to IEEE802.1D;

25   FIG. 24 is an explanatory diagram of flooding occurred;

FIG. 25 is an explanatory diagram of the

occurrence of the flooding when in a steering
operation due to the failure;

FIG. 26 is a diagram showing an example of the
RPR network having the station connected to two
5   bridges (a normal state);

FIG. 27 is a diagram showing an example of the
RPR network having the station connected to two
bridges (a failure state between the bridge and the
off-the-ring station);

10   FIG. 28 is a diagram showing plans of a method
of solving a problem arising from the frame
transmission to all the nodes on the rings;

FIG. 29 is an explanatory diagram of a plan of
adding the MAC address to the RPR format;

15   FIG. 30 is an explanatory diagram of a plan of
distinguishing an existence of the MAC address by
attaching a flag to a RPR header;

FIG. 31 is an explanatory diagram of a plan of
encapsulating the MAC frame;

20   FIG. 32 is an explanatory diagram of a process
(a process in a case where the destination RPR MAC
address is designated to be broadcast) in a case
where a mapping MAC address is not registered in a
translation table; and

25   FIG. 33 is an explanatory diagram of a process
(a process in the case where the destination RPR MAC
address is designated to be broadcast) in a case

where the mapping MAC address is not registered in
the translation table.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

5   Embodiments of the invention will hereinafter
be described with reference to the drawings. Note
that constructions of the embodiments are an
exemplification, and the invention is not limited to
the constructions of the embodiments.

10   [Outline of the Invention]
          To start with, an outline of the invention will
be explained. FIG. 1 is a diagram showing a format
translation method according to the invention, and
FIG. 2 is an explanatory diagram of a frame

15   transmission in a case where a mapping relationship
of a MAC address is not yet learned.

          A format translation applied to the invention
is shown in FIG. 1. This format translation is of
the same encapsulation system as the C-plan given by

20   way of the prior art. To be concrete, a MAC frame
(EMAC frame) is encapsulated into a RMAC frame as
follows. Namely, the whole EMAC frame is set as a
payload (a user data field) of the RMAC frame; and a
RPR header, a RPR MAC destination address (RPR MAC

25   DA), a RPR MAC source address (RPR MAC SA), a ET
(Ethernet Type), a HEC (Header Error Check bit) and a
FCS (Frame Check Sequence), are added to the payload

as shown in FIG. 1, thereby assembling a RMAC frame.

At this time, the MAC DA of the EMAC frame is translated into a RPR MAC address mapping thereto by use of a MAC address (EMAC address)-RPR MAC address
5   translation table (retained on a RPR node that executes the encapsulation), and this is set as a RPR MAC DA of the RMAC frame. Further, a MAC address (a self-node address) of the RPR node that executes the encapsulation is set as a RPR MAC SA of the RMAC
10   frame. Moreover, the ET of the EMAC frame is copied and is set as an ET of the RMAC frame. Then, re-calculated values are set as a HEC and a FCS of the RMAC frame. The invention does not, however, unlike the C-plan, require registering a net ET (Ethernet
15   Type).

Further, the invention is applied to a RPR ring (a RPR network) configured of a plurality of station nodes and a plurality of bridge nodes. A frame transmission process in the RPR network is
20   substantially the same on the bridge node and on the station node.

Concretely, it is judged whether a destination node (a node designated by the MAC DA) of a receipt frame is the station node or the bridge node, the
25   encapsulation shown in FIG. 1 is effected in the case of the bridge node, and the transmission is executed without performing the encapsulation (through a

transparent translation (see FIG. 23)) in a case where it is not (but is the station node).

Through this, if the frame destination node is the bridge node, the receipt frame is invariably

5   encapsulated and thus sent, and if the destination node is the station node, it is not invariably encapsulated and is thus sent.

Accordingly, the station node, upon receiving the frame, executes a process for the non-

10   encapsulated frame, and the bridge node may, upon receiving the frame, execute a process for the encapsulated frame. This eliminates a necessity of judging whether the Ethernet type based encapsulation has been done or not. Hence, a registration of a new

15   Ethernet type becomes unnecessary.

Furthermore, for actualizing the invention, the RPR node on the frame transmitting side is required to know whether the destination station is the station node on the ring or a station connected to

20   the bridge node. Information for judging this is acquired from a topology map table as updated information about the respective RPR nodes on the ring, the map table being retained on each RPR node on the ring.

25   Namely, each RPR node, on the occasion of transmitting the frame, searches as to whether or not the MAC address (MAC DA) of the destination node

exists in a MAC address group registered in the
topology map table thereof, if it exists on the
topology map table, the destination node is the
station node on the ring, and hence its transmission
5   is conducted without performing the encapsulation.

If the destination node MAC address in the
frame does not exist in the topology map table, it
follows that there occurs a transmission to a station
outside the ring that is connected to the bridge node,
10 and hence it may be transmitted after being
encapsulated.

For effecting the encapsulation, it is the same
as the plans A-C described in the prior art to create,
learn and refer to a link mapping table (a
15 translation table) for the MAC addresses of the
bridge nodes on the ring and the MAC addresses of the
stations subordinate thereto.

Further, there is the case where the MAC
address mapping relationship is not yet learned in
20 the transmission of the frame. In this case, it is
required that the frame be transmitted to all the
bridge nodes on the ring. At this time, if a
broadcast address is used as the destination node MAC
address, the station nodes on the ring also become
25 recipients.

Such being the case, a multicast address is
used for solving the problem. Namely, a multicast

address to one group into which all the bridge nodes on the ring are aggregated, is prepared and registered on each of the bridge nodes. Then, as shown in FIG. 2, in the case where the RPR MAC

5   address corresponding to the destination node MAC address of the frame is not yet learned (in a case where the RPR MAC address mapping thereto is not yet registered in the table), it is used for transmitting the frame to all the bridge nodes.

10   If done in this way, only the bridge nodes on the ring can receive the frame. At this time also, the station node just lets the multicast frame pass through. Even if the station node executes a process of discarding the multicast frame, the station node

15 can deal with also the encapsulated frame, and therefore any problem does not arise in the discarding process (see FIG. 2).

    As described above, according to the invention, it is possible perform the communications between all

20 the bridge nodes and station nodes on the RPR without adding any change to the packet format in the present rules, and also to provide the MAC bridging system having a small load in communications.

    [Embodiment]

25   FIG. 3 is a diagram showing an IP network model by way of an embodiment of the invention. FIG. 4 is an IP/MAC address table on each device (the RPR node)

in the embodiment. FIG. 5 is a diagram showing an
example of the topology map table retained on each
RPR node shown in FIG. 3.

<Outline>

5   At first, an outline of the network system in
the embodiment will be explained. In FIG. 3, devices
RA, RB, BC, BD, RE, BF are RPR nodes, and the RPR
nodes are constructed of station nodes RA, RB, RE
having a function as a router, and of bridge nodes BC,
10 BC, BF having a function as a bridge. These six
pieces of RPR nodes configure one ring network. Each
of these RPR nodes, through transferring and
receiving a topology discovery packet, has already
structured the topology map table shown in the table
15 in FIG. 5 inwardly of the device.

S1-S6 shown in FIG. 3 are stations residing
outside (off the ring) the RPRT network and capable
of transmitting and receiving the IP frame. These
stations S1-S6 have already acquired the IP addresses
20 of all the devices including the RPR network. The
respective device MAC addresses corresponding to the
IP addresses are not yet learned. Further, each of
the RPR nodes does not yet learn the MAC address of
each station off the ring.

25   Moreover, the all the nodes have already known
the MAC address (MAC) to the group which the bridge
nodes BC, BD, BF on the RPR network belong to, and

only the respective bridge bodes BC, BD, BF can execute a process of receiving this.

<Operational Example>

Next, an operational example of the network system in the embodiment will be described. In the network illustrated in FIG. 3, the operational example in data transmission/receipt (A) and (B) shown as below, will be explained.

(A) Data Transmission to Station S6 from Station S1

FIG. 6 is an explanatory diagram of an ARP frame format between stations S1 and S6. FIG. 7 is an explanatory diagram of a format of an IP data packet transferred and received between the stations S1 and S6.

In the case of transmitting the IP data frame to the station S6 from the station S1, to begin with, the station S1 is required to know the MAC address of the station S6. Therefore, an ARP (Address Resolution Protocol) packet is sent to the network, and the MAC address of the station S6 is acquired. A frame format of the ARP packet is shown in FIG. 6.

A destination address of the frame (the ARP frame: see FIG. 6A) transmitted from the station S1 is broadcast (DA = BC). Therefore, a transparent transmission according to the rules is conducted. Namely, the bridge node BC, which is connected to the

station S1 and receives the ARP frame, sets a RPR

header, a HEC and a recalculated FCS in the ARP frame,

thereby translating the ARP frame (effecting a

transparent translation) into a RPR-based format (see

5   FIG. 6B).

Thereafter, the bridge node BC, the destination

address of the ARP frame being the broadcast, the ARP

frame is transmitted toward the RPR ring round an

inner circle and an outer circle in both ways so that

10   the ARP is received by all the nodes on the RPR.

At this time, the bridge node BC, if not

learning about the RPR node accommodating the station

S6, sends the ARP frame having the format shown in

FIG. 6A also to the station S2.

15   Further, the bridge node BC, with a trigger

that the frame is received from the station S1,

learns that the station S1 is connected as a

subordinate to the self-device. Namely, the bridge

node BC registers a mapping relationship between the

20   MAC address (MS1) of the station S1 and the MAC

address (MBC) of the self-device (the bridge node BC)

in the MAC address translation table.

A destination address of the ARP frame (see FIG.

6B) sent to the RPR network (the RPR ring) is the

25   broadcast. Therefore, all the nodes on the ring

receive it. At this time, each of the station nodes

RA, RB, RE receives and analyzes the ARP frame. Each

of the station nodes RA, RB, RE, since a mapping IP
address for obtaining the MAC address is different
from a self IP address, does not respond to the ARP
packet.

5   By contrast with this, each of the bridge nodes
BD, BF, upon receiving the ARP frame, because of the
destination address (RPR MAC DA) being the broadcast
(which means that it is not the MAC address of the
bridge node), judges that the ARP frame is not

10 encapsulated. In this case, each of the bridge nodes
BD, BF deassembles the ARP frame back to the original
format (FIG. 6A) and thus transmits it to the
subordinate station (it operates as being
transparent).

15   Eventually, only the station S6 can respond to
the ARP frame (for the reason that the mapping IP
address set in the ARP frame is the IP address of the
station S6). The station S6, upon receiving the ARP
frame, sends an ARP response frame mapping thereto in

20 a format shown in FIG, 6C to the bridge node BF.

The bridge node BF checks a destination node
(destination) address (= MS1) of the ARP frame
received from the station S6 and, this not existing
in the topology map table (see FIG. 5), judges that

25 the MAC address is a MAC address of a station off the
ring.

Further, the bridge node BF does not yet learn

about where the bridge node to which the station
(that is herein the station S6) specified by the
destination address is connected, is located. Hence,
the bridge node BF assembles a RPR frame into which
5   the ARP frame from the station S1 is encapsulated in
FIG. 6D by use of a multicast address (= MC) set for
the bridge group, and sends it onto the RPR ring. A
RPR destination address of the RPR frame is the
multicast address. Therefore, the RPR frame is
10   received only by each of the bridge nodes BC, BD on
the RPR ring.

Each of the bridge nodes BC, BD, the
destination address of the RPR frame being the
multicast address (the frame destination being the
15   bridge node), judges that the MAC frame (the EMAC
frame) is encapsulated into the RPR frame, then
decapsulates it to extract a body frame (the ARP
frame) and sends it to the devices (the respective
stations off the ring) subordinate to the node itself.
20   At this time, each of the bridge nodes BC, BD
learns that the station S6 is connected subordinately
to the bridge node BF. Namely, each of the bridge
nodes BC, BD registers in the translation table a
source address (SA = MBF) of the RPR frame and a
25   source address (SA = MS6) of the MAC frame (the ARP
frame) encapsulated into this in a way that makes
them corresponding to each other.

Then, the ARP frame sent to the stations (which are herein the stations S1, S2, S3, S4) off the ring, is received only by the station S1. Thus, the station S1 can acquire the MAC address of the station S6.

Next, the station S1 transmits an IP data packet (an IP frame) as an essential transmission object to the bridge node BC in a frame format shown in FIG. 7A.

The bridge node BC receives the IP frame from the station S1 and can, because of its destination address being the MAC address of the station S6 (which is not registered in the topology map table), recognize that the destination of the IP frame is not the node on the RPR ring but the station S6 subordinate to the bridge node BF that has been already learned (already registered in the translation table).

Therefore, the bridge node BC assembles a RPR frame (see FIG. 7B) into which the IP frame from the station S1 has been encapsulated with a RPR header designating the MAC address of the bridge node BF to a destination address, and sends it onto the RPR ring.

Only the bridge node BF receives the RPR frame. The bridge node BF recognizes, as the destination is not designated to the broadcast, that the IP frame has been encapsulated. Accordingly, the bridge node

BF decapsulates it and transmits the body IP frame to the station S6. The transmission and the receipt of the data (the IP frame) between the station S1 and the station S6 are thereby completed.

5   Note that the bridge node BF, when receiving the RPR frame, can learn (can register in the translation table) from the its source MAC address and the source MAC address of the encapsulated MAC frame that the station S1 is connected subordinately

10   to the bridge node BC. Therefore, the frame transmission in a reversed direction, i.e., from the station S6 to the station S1 can be done from this onwards in the same way as the IP frame has been sent to the station S6 from the station S1.

15   (B) Data Transmission from Station Node RA to Station S3

FIG. 8 is an explanatory diagram of an ARP frame format between a station node RA and the station S3. FIG. 9 is an explanatory diagram of a

20   format of the IP data packet between the station node RA and the station S3.

In the case of transmitting the frame to the station S3 from the router node RA, as in the case (A), before the router node RA sends the IP frame to

25   the station S3, there is required a procedure of knowing the MAC address of the station S3 trough the ARP packet. FIG.8 shows a frame format related to a

RA→S3 ARP.

A destination MAC address of the ARP frame transmitted from the router node RA is a broadcast address (see FIG. 8A). Therefore, each node on the
5 ring can receive the ARP frame. At this time, each of the station nodes RB, RE receives and analyzes the ARP frame but does not respond to this because of not being its own IP address.

On the other hand, each of the bridge nodes BC,
10 BD, BF, when receiving the ARP frame, judges that this is not encapsulated, because the destination MAC address is the broadcast address, then performs the transparent translation and transmits it in a format shown in FIG. 8B to the subordinate station.

15   Eventually, the station S3 receives the ARP frame. The station S3 sends to the bridge node BD an ARP response frame (having a format shown in FIG. 8C) to the ARP frame.

The bridge node BD checks a destination MAC
20 address of the ARP response frame. At this time, the destination MAC address is given such as "DA = MRA" and is registered in the topology map table. Hence, the bridge node BD can recognize that the destination is addressed to the node on the ring. Therefore, the
25 bridge node effects the transparent translation into the RPR forma without encapsulating and sends it (see FIG. 8D).

A destination f the RPR frame (the ARP response frame) is a station node RA. Accordingly, only the station node RA can receive the RPR frame

From the RPR frame, the router node RA learns
5   that the station S3 exists subordinately to the bridge BD, and completes an acquisition of the MAC address of the station S3.

Next, the router node RA sends the IP data packet (the IP frame) as an essential transmission
10   object to the station S3 as it is addressed thereto. Namely, the router node RA assembles a RPR frame (see FIG. 9A) into which the IP frame is encapsulated, and sends it.   A destination MAC address of the RPR frame designates the bridge node BD (DA = MBD).
15   Therefore, the bridge node BD receives the RPR frame.

The bridge node BD decapsulates the RPR frame and transmits a body frame (the IP frame) to the station S3. The station S3 receives the IP frame from the bridge node BD. Thus, the transmission and
20   receipt of the data (the IP frame) between the RA and S3 are completed.

In a case where the station S3 sends the IP data packet (the IP frame) to the router node RA, the IP frame having the format shown in FIG. 9(b) is sent
25   to the bridge node BD.

The bridge node BD assembles the RPR frame (see FIG. 9C) into which the IP frame from the station S3

has been transparent-translated, and transmits it to
the station node RA. The router node RA can thereby
receive the IP frame from the station S3.

Two data transmission patterns in the network

5   illustrated in FIG. 3 have been shown so far. As a
matter of course, also between other stations,
bridges and routers, if the frame is assembled based
on the rule of the invention, the frame can be
transmitted and received within the IP network by

10   deassembling back to the original frame outside in
accordance with the present specified format on the
RPR.

<Structure of Bridge Node>

Next, an example of a structure of the bridge

15   node will be explained. FIG. 10 is a diagram showing
the example of the architecture of the bridge node,
and FIG. 11 is a block diagram showing a structure of
a RPR card shown in FIG. 10. FIG. 12 is a diagram
showing an example of a data structure of a learning

20   table/MAC address mapping table.

A bridge node 10 illustrated in FIG. 10 can be
applied as each of the bridge nodes BC, BD, BF in FIG.
3. The bridge node 10 includes an Ethernet card
(Ethernet Card) 11 connected to the stations off the

25   ring via an Ethernet circuit, a Giga Ethernet card
(Giga Ethernet Card) 12 connected to the stations off
the ring via a Giga Ethernet circuit, a RPR card (RPR

Card) 13 connected to the RPR ring, a switch (SW) 14,
connected to the cards 11 through 13, for
transferring and receiving the MAC frame between the
cards by its switching operation, and a CPU card (CPU

5   Card) 15 for controlling the cards 11 through 13 and
the switch 14.

Each of the RPR card 13, the Ethernet card 11
and the Giga Ethernet card 12 is a card for
processing the MAC frame at an Interface speed and on

10   a protocol. The CPU card 15 performs a role of
managing the cards 11 through 13 and controlling the
switch 14 as an interface between the cards.

Upon an input of the MAC frame to a certain
card among the cards 11 through 13, the card searches

15   through a learning table with the destination MAC
address of the MAC frame being used as a key, and, if
already learned, forwards it to other relevant card.
At this time, if not learned, it floods the MAC frame
to all other cards.

20   Thus, the learning tables called "MACLEARN"
exist in the respective cards 11 through 13, and are
managed by the CPU card 15 to have the same learning
content.

Further, the individual cards 11 through 13 are

25   managed based on port numbers, and the learning table
retains the learning content (which is a mapping
relationship between the port numbers and the MAC

addresses of the subordinate devices) in a form that shows which MAC address the device connected subordinately to the port number has.

The RPR card 13 is a card for executing a protocol process according to the invention. As shown in FIG. 11, the RPR card 13 includes a switch interface (SW-INF) 21 connected to the switch 14 (FIG. 10), an L2 engine (L2 Engine) 22 connected to the switch interface 21, RPR MAC modules (constructed of LSIs) 23, 24 each connected to the L2 engine 22, and physical interfaces (PHY-INF) 25, 26 connected respectively to the RPR MAC modules 23, 24.

Further, a topology map table 27, a learning table (MAClearn table) 28 and a MAC address mapping table 29 are connected to the L2 engine 22, and are referred to and/or updated depending on a process by the L2 engine 22.

The RPR is of dual rings, and hence there are prepared the two physical interfaces 23, 24 accommodating respectively outer and inner communication lines. The physical interface 25 accommodates the outer line for receiving the frame and an inner line for transmitting the frame, while the physical inter face 26 accommodates the inner line for receiving the frame and the outer line for transmitting the frame.

The L2 engine (L2_Engine) 23 executes processes

including the protocol process according to the
invention. The L2 engine 23 selects one of the RPR
MAC modules 23, 24 in accordance with the destination
MAC address of the frame that should be forwarded to
the RPR ring, and gives the frame to the selected RPR
MAC module. It is thereby automatically determined
which side (outer/inner: Outer/Inner) of the dual
rings the frame is forwarded to.

Each of the RPR MAC modules 23, 24 translates
the MAC address into a final RPR format. Herein, the
transparent translation and the encapsulation are
carried out.

Three categories of main tables exist in the L2
engine 22. The first table is the topology map table
27 necessary for the RPR protocol process. The
topology map table 27 has the data structure shown in
FIG. 5, and manages the MAC addresses, TTLs, etc. of
the respective nodes on the ring.

The second table is the learning table (MAC
learning table) 28 that corresponds to the learning
table explained in FIG. 10. The learning table 28 is
registered with a mapping relationship between the
port number retained the RPR card 10 and the MAC
address of the device connected to a port having the
port number.

The third table is the MAC address mapping
table 29. The MAC address mapping table 29 is

registered with a mapping relationship between the
MAC addresses of the stations subordinates to the
node on the ring on the RPR side and the MAC
addresses of the nodes themselves. The MAC address

5   mapping table 29 corresponds to the translation table
shown in FIG. 1.

The MAC learning table 28 can be merged with
the MAC address mapping table 29. FIG. 12 is a
diagram showing an example of a data structure of a

10   table (MAC learn/MAC mapping table) 30 into which the
table 28 and the table 29 are merged.

As sown in FIG. 12, the table 30 can be
registered per node on the ring by learning with
records each consisting of a node name (a device

15   name), a MAC address of the node, a name (a device
name) of the station off the ring that is connected
to the node, a MAC address of the station and a port
number corresponding to the station.

The RPR card 13 shown in FIG. 11 is

20   preinstalled also into each station node on the ring.
<Processing Flow>

Next, processes of the station off the RPR ring,
the station on the RPR ring and the bridge node, will
be explained. FIG. 13 is a flowchart showing a RPR

25   MAC frame transmitting process by the station node,
FIG. 14 is a flowchart showing a RPR MAC frame
transmitting process by the bridge node, FIG. 15 is a

flowchart showing a RPR MAC frame receiving process by the bridge node, and FIG. 16 is a flowchart showing a RPR MAC frame receiving process by the station node.

5   These processes are executed chiefly by the RPR cards preinstalled into the station nodes and the bridge nodes. The respective processes will hereinafter be described.

      <<Frame Transmitting Process by Station Node>>

10   The station node, in the case of transmitting the IP data packet to a predetermined party (which is, e.g., an arbitrary station off the ring), executes the process shown in FIG. 3.

      At first, the station node searches for a MAC

15 address corresponding to a destination node (destination) IP address (step S01), and judges whether the MAC address is discovered (known) or not (step S02).

      At this time, in case the MAC address is

20 discovered (S02: Y), the processing proceeds to step S04. Whereas if not (S02: N), the station node acquires the MAC address mapping thereto by the ARP packet transmitting process, and returns the processing to step S01.

25   In step S04, the station node assembles a MAC frame (including the IP data packet) in which the discovered MAC address is set in a destination MAC

address.

Next, the station node searches for a
destination MAC address of the MAC frame by referring
to the topology map table (see FIG. 5) (step S05),
5   and judges whether or not the destination MAC address
is discovered (registered in) from the topology map
table (step S06).

At this time, in case the destination MAC
address is discovered (S06: Y), the transmitting
10   destination is the station on the ring, and therefore
the station node modifies the MAC frame into a RPR
format (effects the transparent translation), and
forwards it onto the RPR ring (step S07). Upon an
end of step S07, the transmitting process is finished.

15   While on the other hand, in case the
destination MAC address is not discovered in step S06
(S06: N), the station node searches (Search) the
MAClearn/MAC mapping table (retained on the station
node) for the destination MAC address (step S08), and
20   judges whether the destination MAC address is
discovered or not (step S09).

At this time, in case the destination MAC
address is discovered (S09: Y), the destination is
the station off the ring that is subordinate to the
25   bridge node, and the MAC address of the bridge node
to which the station is connected, is known (which
has already been registered in the MAClearn/MAC

mapping table). Therefore, the station node acquires
the MAC address of the bridge node that is set
corresponding to the destination MAC address from the
MAClearn/MAC mapping table (step S10).

5   Subsequently, the station node encapsulates, in
the RPR format, the MAC frame assembled in step S04,
and transmits it (step S11). At this time, the
station node sets the MAC address of the bridge node
that has been obtained in step S10 as a destination
10   MAC address in the RPR format. Upon finishing the
process in step S11, the transmitting process is
terminated.

     In case the destination MAC address is not
discovered in step S09 (S09; N), the destination is a
15   station off the ring that is subordinate to the
bridge node, however, a state is that the MAC address
of the bridge node to which the station is connected,
is unknown (not yet registered in the MAClearn/MAC
mapping table). Therefore, the station node
20   encapsulates the MAC frame in a way that sets the
multicast address to the bridge group as a
destination MAC address in the RPR format, and sends
it (step S12). Upon finishing the process in step
S12, the transmitting process is terminated.

25   <<Frame Transmitting Process by Bridge Node>>
     Next, a frame transmitting process by each
bridge node on the RPR ring will be explained. As

shown in FIG. 14, the bridge node 10 (FIG. 10)
receives through the Ethernet card 11 or the Giga
Ethernet card 12 the MAC frame (including, e.g., the
IP data packet) from the station subordinate to the

5   node 10 itself (S001). The received MAC frame, in
the case of its being sent to the RPR ring, forwarded
to the RPR card 13 via the switch 14 (step S002).

Thereupon, in the RPR card 13, the L2 engine 22
(FIG. 11) receives the MAC frame via the switch

10 interface 21, and extracts a destination MAC address
out of the MAC frame (step S003).

Next, the L2 engine 22 searches through the
topology map table 27 as to whether the destination
MAC address is registered therein or not (step S004),

15 and judges whether the destination MAC address is
discovered or not (step S005).

At this time, in case the destination MAC
address is discovered (S005; Y), the transmitting
destination is a station on the ring, and hence the

20 L2 engine 22 gives the MAC frame to the corresponding
RPR MAC module in accordance with the contents stored
in the topology map table. The RPR MAC module, when
receiving the MAC frame from the L2 engine 22,
modifies the MAC frame into the RPR format (the

25 transparent translation).

The translated MAC frame (a RMAC frame) is sent
onto the RPR ring from the corresponding physical

interface (step S006). Upon an end of step S006, the transmitting process is finished.

While on the other hand, in step S005, in case the destination MAC address is not discovered (S005;

5   N), the L2 engine 22 searches the MAClearn/MAC mapping table 30 for the destination MAC address (step S007), and judges whether the destination MAC address is discovered or not (step S008).

A this time, in case the destination MAC

10 address is discovered (S008; Y), the destination is a station off the ring that is subordinate to the bridge node, and the MAC address of the bridge node to which the station is connected, is known (which has already been registered in the MAClearn/MAC

15 mapping table 30). Therefore, the Le engine 22 acquires the MAC address of the bridge node that is set corresponding to the destination MAC address from the MAClearn/MAC mapping table 30 (step S009).

Subsequently, the L2 engine 22 forwards the MAC

20 frame together with the MAC address obtained from the table 30 to the corresponding RPR MAC module in accordance with the contents in the topology map table 27.

The RPR MAC module encapsulates, upon receiving

25 the MAC frame and the MAC address from the L2 engine 22, the MAC frame into the RMAC frame, and sets the MAC address in a destination MAC address of the RMAC

frame.

Thereafter, the RMAC frame is sent onto the RPR
ring via the corresponding physical interface (step
S010). Upon finishing step S010, the transmitting
5   process is terminated.

In step S008, in case the destination MAC
address is not discovered (S008; N), the destination
is a station off the ring that is subordinate to the
bridge node, however, a state is that the MAC address
10   of the bridge node to which the station is connected,
is unknown (not yet registered in the MAClearn/MAC
mapping table 30). Therefore, the L2 engine 22
forwards the MAC frame and a multicast address
(retained previously) to the bridge node group to the
15   corresponding RPR MAC module in accordance with the
contents of the topology map table.

The RPR MAC module, upon receiving the MAC
frame and the multicast address from the L2 engine,
encapsulates the MAC frame into the RMAC frame and
20   sets the multicast address in a destination MAC
address of the RMAC frame. Thereafter, the RPR frame
is sent onto the RPR ring via the corresponding
physical interface (step S011). Upon finishing step
S011, the transmitting process comes to an end.

25   <<Frame Receiving Process by Bridge Node>>

Next, a frame receiving process by the bridge
node will be described. As shown in FIG. 15, the

bridge node 10 (FIG. 10) receives through the RPR

card 13 the frame (RMAC frame) from the RPR ring.

In the RPR card 13, a source MAC address (SA)

of the RPR frame (the RMAC frame) is checked (step

5 S101), and it is judged whether the source MAC

address is a self-device address or not (step S102).

At this time, in case the source MAC address is the

self-device address (S102; Y), the frame is discarded

(step S103), and the receiving process is finished.

10 Whereas if the source MAC address is not the

self-device address (S102; N), a destination MAC

address of the RPR frame (the RMAC frame) is checked

(step S104), and it is judged whether the destination

MAC address is the self-device address or not (step

15 S105).

At this time, in case the destination MAC

address is the self-device address (S105; Y), the

processing proceeds to step S109, and in case it is

not (S105; N), the processing proceeds to step S106.

20 In step S106, it is judged whether or not the

destination MAC address is the multicast address to

the bridge group, and the processing proceeds to step

S110 in case it is the multicast address (S106; Y)

and proceeds to step S107 in case it is not (S106; N).

25 In step S107, it is whether or not the

destination MAC address is the multicast address to

the bridge group, in case it is the broadcast address

(S107; Y), the processing proceeds to step S111, in case it is not (S107; N), the RMAC frame is transmitted to a next device (neighboring node) (step S108), and the receiving process is finished.

5   In step S109, the RMAC frame is captured in the device (the bridge node), and the processing proceeds to step S112.

In step S110, the RMAC frame is captured in the device (the bridge node) and also transmitted to the

10   next device (the neighboring node), and the processing proceeds to step S112.

In step S111, the RMAC frame is captured in the device (the bridge node) and also transmitted to the next device (the neighboring node), and, assuming

15   that the packet (the MAC frame) is not encapsulated, the processing proceeds to step S114.

In a step S112, it is judged whether a PT ((packet type) (packet classification): see FIG. 17) in the RPR header of the RMAC frame is "data packet

20   (11)" or not. In case the packet type is the data packet, it is assumed that the packet (MAC frame) has been encapsulated into the RMAC frame, and the processing proceeds to step S113.

In a step S113, the RMAC frame is decapsulated,

25   the body frame (the MAC frame) is forwarded to the card (the Ethernet card of Giga Ethernet card) via the switch 14 in accordance with the destination MAC

address and further forwarded to the subordinate
device (the station) from the card. Upon an end of
step S113, the receiving process is finished.

In step S114, the packet type (other than the
5   data packet) in the RPR header of the RMAC frame is
checked, and the packet (the user data field) in the
RMAC frame is transferred to the protocol processing
unit corresponding to the packet type. Upon
finishing step S114, the receiving process is
10   terminated.

<<Frame Receiving Process by Station Node>>
Next, a frame receiving process by the station
node will be described. As shown in FIG. 16, when
the station node receives the RPR frame (the RMAC
15   frame) from the RPR ring, a source MAC address (SA)
of the RMAC frame is checked (step S201), and it is
judged whether the source MAC address is a self-
device address or not (step S202).

At this time, in case the source MAC address is
20   the self-device address (S202; Y), the frame is
discarded (step S203), and the receiving process is
finished. By contrast with this, in case the source
MAC address is not the self-device address (S202; N),
a destination MAC address of the RPR frame (RMAC
25   frame) is checked (step S204), and it is judged
whether the destination MAC address is the self-
device address or not (step S205).

At this time, the processing proceeds to step S208 in case the destination MAC address is the self-device address (S205; Y), and proceeds to step S206 in case it is not (S205; N).

5 In step S206, it is judged whether the destination MAC address is a broadcast address or not, in case it is the broadcast address (S206; Y), the processing proceeds to step S209, while in case it is not (S206; N), the RMAC frame is sent to a next

10 device (a neighboring node) (step S207), and the receiving process is terminated.

In step S208, the RMAC frame is captured in the device (the station node), and the processing advances to step S210.

15 In step S209, the RMAC frame is captured in the device (the station node) and transmitted to the next device (the neighboring node), and the processing proceeds to step S210.

In step S210, the packet type in the RPR header

20 of the RMAC frame is checked, and the packet (the user data field) in the RMAC frame is transferred to the protocol processing unit corresponding to the packet type. Upon finishing step S210, the receiving process is terminated.

25 [Others]

The embodiment described above discloses the following inventions. The following inventions can

be properly combined. Note that the invention can be applied to a single ring in addition to the dual rings on which the RPR protocol functions. For example, one of the dual rings is so set as not to

5 work due to a failure, and so on. Alternatively, on the occasion of forwarding the received MAC frame to any one of the rings, only one-side ring is invariably selected. Thus, the invention can be applied to the single ring. It is obvious that the

10 kind of implementation can be easily embodied by those skilled in the art.

　　According to the invention, it is possible to provide the RPR-network-related technology that eliminates the necessity for the flag for

15 distinguishing and the ET indicating that the MAC address is added and the frame is encapsulated.

　　Further, according to the invention, it is feasible to provide the RPR-network-related technology including means by which only the bridge

20 node on the ring receives the frame with its address unknown.